

THURSDAY, AUGUST 29, 1878

## THE ECLIPSE

THE telegram sent from Denver, signed by Professors Young and Watson, Dr. Draper, and myself, will have given an idea of the results which we think have been secured on the eclipse of this year. Since the telegram was despatched I have been engaged in making as many notes on the various points of detail as incessant travel and a temperature of 91° in the shade would permit. A long time must elapse before anything like a general view of the total work done is possible, but I think that the readers of NATURE may rely upon the correctness of what I have collected, though it is quite possible, as I have not succeeded in finding all the observers, that some errors may have crept in. And again, it is quite possible that the many dry plates taken and even yet not developed, may contain information of which at present we have no idea. To take an instance: we do not yet know whether Prof. Harkness's attempt to photograph the polariscopic phenomena presented by the corona was successful or not, for I learn at the Naval Observatory here that he is still at Fort Steele, handing over his camp equipment to the military, who all along the line have been placed in the most unreserved way at the disposal of the different parties by the express orders of Gen. Sherman himself, who takes the greatest interest in such inquiries, and is anxious to foster scientific inquiries as far as in him lies. Strange as it may seem, this is the expressed feeling of all the authorities here, from the Chief of the State downwards. In interviews with which I have been honoured, the President of the United States himself, the Secretary for War, Gen. Sherman, and other members of the Cabinet, have one and all insisted upon the importance of securing records of all possible natural phenomena, and expressed their gratification that such records have been secured in the present instance by Government aid.

I will begin the extracts from my notes by referring to the appearance of the Corona itself.

I give a rough sketch of what I saw of the corona with the naked eye (Fig. 1), slightly exaggerating the dimensions of the streamers to show the wind-vane appearance, which, to me, was almost perfect, being pointed at one end and bounded by parallel edges at the other; others, I may say, however, saw a resemblance to a fish's tail. These streamers vanished absolutely in the telescope (Fig. 2), as did the radiating lines in 1871; not a shred of them was left. Prof. Cleveland Abbe (lying on his back at a height of eleven feet on Pike's Peak; he had been sent down the day before from the summit, as the rarefaction of the air was too much for him) saw them, with the naked eye, extending to a distance of six degrees on either side, and their appearance suggested to him meteoric streams for their origin. Prof. Newcomb also saw them with the naked eye when he had hidden the corona behind a screen. To him they suggested the zodiacal light, or rather its nucleus near the sun, even if it extend beyond the orbit of the earth.

These streamers seem to have been seen by everybody, and were doubtless cosmical; a system at right angles to them (they lay along the ecliptic), and quite as bright,

was recorded by many, though many of the best observers saw not a trace of them.

Here is a lesson, and one which affords an explanation of a great deal of eclipse work, connected with these outliers of the corona.

I had a magnificent view of the corona with a power of 50 on my 3 $\frac{1}{4}$ -inch Cooke, and saw exquisite structure at the north and south points. Curves of contrary flexure started thence, and turned over, and blended with the rest of the corona, which was entirely structureless and cloud-like; the filamentous tracery which in India I observed till three minutes after totality had ended had all gone. Prof. Bass, however, tells me that by confining his attention to the same point for nearly the whole of totality, the structure came out, and seemed to pulsate like an aurora.

Prof. Hall is almost the only one who is under the impression that the corona of 1869 was less brilliant than this.

Mr. Burnham, who is an observer of the highest order, thus gives his opinion, which agrees with that of Prof. Young, who remarked its unusual faintness and lack of polar extension, and all the other American astronomers:—

"The coronal display was far less than in the eclipse of 1869, as seen at Des Moines, Iowa, by members of the *Times* party, and it bore a more striking resemblance, probably, to the eclipse of 1870, as seen at Gibraltar and in the Island of Sicily. The corona was, in fact, a mild affair, according to the observations of this party, as compared with that seen in other eclipses. A few protuberances were seen, and several bright streamers. On one side there was observed a bright pink ribbon or crescent. The traditional bright lines (the rays) and dark patches (the rifts) were not nearly as conspicuous as usual."

Mr. Burnham made another interesting observation which may prove one of considerable value in determining the nature of the corona. Anticipating that the star  $\zeta$  Cancri would be very near to the sun, he made special efforts to see it, and was altogether successful, for it was distinctly seen through the corona.

General Myer, the distinguished head of the Army Signal Service, who had given orders to utilise his station on Pike's Peak for eclipse observations, observed the corona himself from the summit, and therefore, under conditions which have never been utilised before. He describes the corona as built up of five radial lines of a golden colour; beyond this in the direction of the ecliptic were prolonged bright silver rays. This was seen with the naked eye. In the telescope the appearance was quite different; a layer close to the sun, only of a light pink colour, was seen, and the long bright silver rays had disappeared. The greater elevation, thus, was more suited to a study of the structure than the lower levels, and at the same time the colour observed seems to have been slightly changed. In the pure air of the Peak, also, he saw the corona steadily for about five minutes after totality, and watched the moon cover the outer striated edge of the corona, which appeared, then, to be more golden than ever.

We next come to the Photographs.

Photographs of the corona and of its spectrum were

obtained at nearly all the stations. In order to give an idea of the extensive preparations which have been made, I may state what were Dr. Draper's photographic appliances as an instance of the equipment at one station.

In the first place there was a telescope of 5 inches aperture, and 78 inches focal length, especially corrected for photography, to get as complete a photograph of the corona as could be obtained by an exposure lasting

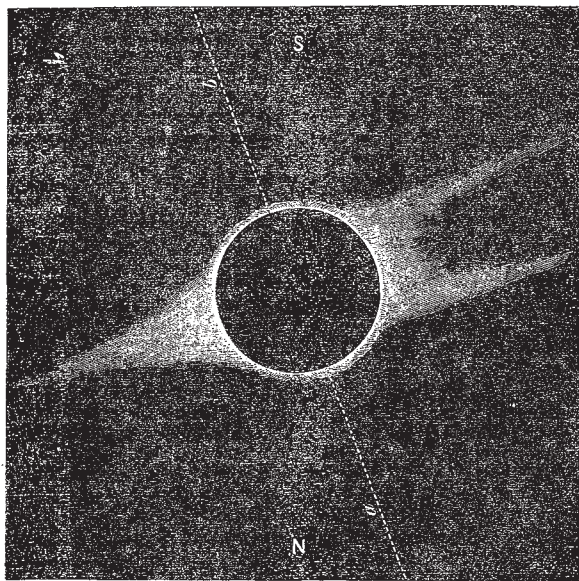


FIG. 1.—Nabeleye.

during the whole of totality. This was during 165 seconds.

Next there was a large instrument which may be called a slitless "phototelespectroscope." This instrument consisted of an object-glass, composed of four lenses 6 inches in diameter and 21 inches focal length. The image of the sun at the focus was less than  $\frac{1}{4}$  of an inch in diameter, and of extreme brilliancy. Before the rays of this lens reached the focus, however, they were intercepted by a Rutherford grating, about 2 inches square,

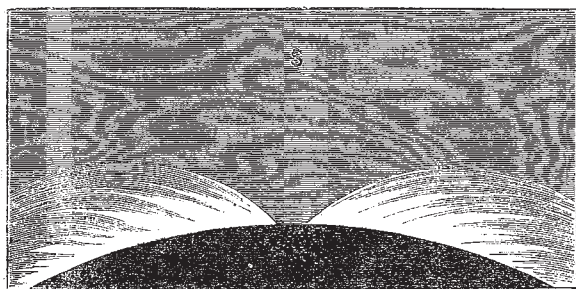


FIG. 2.—Telescope.

set at an angle of 60 degrees. This threw the rays to one side, and produced three images—a central one of the sun, and on either side of it a spectrum. One of these spectra was dispersed twice as much as the other, that is, would give a photograph of twice the length. This last photograph was actually about 2 inches long. With this instrument, mounted equatorially and driven by clock-work, if the light of the corona was due to gas, giving

lines which lay in the actinic region of the spectrum, ring-formed images, one ring for each bright line, would be introduced. On the other hand, if the light of the corona arose from solid or liquid bodies, or was reflected light from the sun, a long band answering to the actinic region of the spectrum alone would be produced. If the light was partly from gas and partly reflected sunlight, a result partly of rings and partly a band would have been obtained.

As there was an impression that it was impossible to obtain a photograph of the spectrum of the corona, Dr. Draper, in order to give the best possible chance of



FIG. 3.—1, image of sun; 2, first order spectrum; 3, second order.

getting such a photograph, resorted to exceedingly sensitive materials, known as the lightning collodion process, furnished by the Messrs. Anthony, of New York. This involved a necessity of distilling a large part of the water used, because at Rawlins the water contains either alkali or sulphur, both of which are deleterious.

Since so many attempts were made, I had better confine my attention to the photographs. I have seen those of Prof. Hall and Dr. Draper. I will first deal with those of the corona itself. The former, taken by a dry-plate process, and, I believe, by means of a large apertured camera of short focus, are very admirable, and

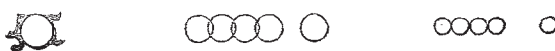


FIG. 4.

show the structure at the north and south points most exquisitely.

One of Dr. Draper's was exposed during the whole of totality, and represents a corona somewhat like those seen in the photographs of the 1871 eclipse taken with a medium exposure. In another, by a fortunate shake of the instrument, a trace of the outline of the chromosphere was received.

Next I come to the Spectra; but first I may be permitted to refer to the only photographic contrivance which was possible for my light marching order. This was a small portrait camera with a lens of one inch aperture,



FIG. 5.

and a Rutherford grating of about 6,000 lines to the inch in front of it to act as a reflector and disperser.

I placed the camera and the attached grating on the ground in such a position that on the focusing screen I got the direct image of the sun at one edge of the plate, and running across the plate the spectra of the first and second orders on one side. A rough notion of what is seen on the plate when the sun is photographed thus will be gathered from Fig. 3.

Now if the corona had been built up of gases competent to give us lines with a spectroscopy of ordinary construction, what I ought to get during an eclipse from



this instrument would have been something like Fig. 4, *provided I had a clockwork arrangement to drive it*. Without this contrivance the image and spectra will travel along the plate in the direction of the sun's motion—Let us suppose as here in Fig. 5.

It will be thus clear that, with this simple contrivance, the result obtained, if clock-work be employed, will be very similar in kind to that arrived at in Dr. Draper's more elaborate arrangement, to which attention has been drawn.

In the spectra, then, thus obtained, we had only one question to solve, as we all thought: we had to determine the position of the rings photographed in the first and second order spectra, or, at all events, in the first. Long before I developed my plate I knew what had happened. Dr. Draper, Prof. Thorpe, and myself, had photographed the spectrum—this I never doubted—but we had photographed as continuous a one as if a platinum wire, or ball, in a state of incandescence, had been in front of our instrument, instead of a shell of hydrogen gas 6' high, as in 1869, and 10' high, as in 1871.

Dr. Draper's plate was exposed during the whole of totality, to make assurance doubly sure. The continuous spectrum has no trace of a ring, though the plate was considerably over-exposed. In my own little photograph the continuous spectrum only is shown, and very clearly. While my plate was being exposed I held a duplicate grating close to the eye, expecting to see the rings as I saw them through five prisms in 1871. In first, second, and third order it was all the same—

Continuous spectrum,  
Continuous spectrum,  
Continuous spectrum;

and it was this which told me of the gigantic change which had taken place in the atmosphere of the great body we were studying.

The remarkable phenomenon thus photographed was of course as remarked by the eye observers; still bright lines were seen in the corona spectrum by one observer, using the term corona to represent everything outside the photosphere, and I make this remark because, whether the spectrum observed was that of the phenomenon which was visible or not I cannot say.

Prof. Young himself and many other observers saw the reversal of many lines at the moment of totality, thereby endorsing Pye and Maclear's observations of 1870 and 1871. After this, to all but Prof. Young the lines vanished utterly, and this was so absolute that in three parties there was consternation and fear, when nothing but a continuous spectra was seen, that something had gone wrong with the instruments.

Prof. Young saw 1474 very faint, *F without C*, and strangest of all, the H and K lines without the long calcium line. This is one of the most remarkable results of the eclipse, and must set students of solar physics to work on a new line. Young thinks the H and K lines were brilliant enough to suggest that the ring in this part of the spectrum photographed in the eclipse of 1875 was really due to them, and I am inclined to agree with him, though why the H and K lines should appear minus the longest line of calcium, passes comprehension, unless

calcium is dissociated there from some cause of which at present we have no idea.

The discovery of a line in the ultra red by means of a thermopile, is another victory gained, and I sincerely hope that at the next eclipse Capt. Abney may use some "red molecules" to photograph it. Mr. Edison, with his wonderful tasimeter, also found indications of heat in the corona, but as he did not use a spectrum, he did not imitate Prof. Young in determining the exact position of the radiation.

We next come to the Dark Lines observed in the corona spectrum.

Janssen was the first to announce the fact that in the corona spectrum the chief Fraunhofer lines were to be seen. This observation was made on the Indian eclipse of 1871. The natural interpretation of this observation is that in the coronal atmosphere there are molecules sufficiently complex to reflect rays of every refrangibility, and that they do in reality reflect the solar light to us as it reaches them.

The observations on this point are a little doubtful, though it is held generally that the balance of evidence is in favour of their appearance. Prof. Barker, who observed with Dr. Draper at Rawlins, saw these lines at the moment that he was dumbfounded, as were most of the observers, at the absence of the bright ones. On the other hand at Prof. Newcomb's camp at Separation they were not traced, Commander Sampson seeing nothing but a perfectly continuous spectrum; 1474, F, and even C being utterly invisible. If the corona gives us light containing the Fraunhofer lines, it can only do so because it reflects solar light. Let us next see, then, what the evidence as to Polarisation is.

When all the observations on this subject are collected we may hope for much new knowledge, but the matter was not finally settled [this time, for here again was a surprise.

Professors Morton and Hastings had arranged to determine the quality of the polarisation observed, Prof. Harkness was to attempt to photograph the phenomena, while Prof. Wright set himself the difficult task of quantifying it. One observer was specially told off to settle the questions raised by Prof. Pickering's observations of 1870. I may commence by saying that these last observations suggest that in 1870 the instrument used by Prof. Pickering was out of order, so that now everybody agrees that there is polarisation.

I have not yet been able to learn anything of the results obtained by Professors Wright and Harkness as the latter used dry plates which were to be developed here, and the Las Animas party took a long mountain trip to shake off the bad effects of a long camping on an alcali plain, and so did not put in an appearance at Denver.

Prof. Morton got radial polarisation most distinctly as I did in India in 1871. The *amari aliquid* is to be found in Prof. Hastings' results, which will be best seen from the following account obligingly placed at my disposal by Prof. Bass, one of his party:—

"The most important and unexpected result of the expedition was reached by Dr. Hastings in his polariscopic observations. It will be remembered that in previous expeditions, and by many observers in the present eclipse, only a few seconds were devoted to the examina-

tion of the corona for polarisation, and this by a bi-quartz or a Savart polariscope, held in the hand so as to take in the whole corona in one view. In the organisation of the expedition, Dr. Hastings was requested to prepare a plan by which the question as to whether the polarisation of the corona was radial or tangential, or absent, could be definitively settled. This was accomplished by an arrangement of apparatus essentially novel.

"The four-inch telescope had a Savart polariscope at its eye end. A diaphragm perforated with holes, 3', 4', 5', 8', 10', 16' was interposed between the polariscope and the objective, and the polarisation phenomena of a definite and limited portion of the corona were thus seen. Diaphragms of 3' and 5' were alone used. The telescope was pointed by Lieut. Very to six points, the first one above the sun and 50' from the circumference; the second one 25' from the circumference and 45° from the vertical; the third 1½' from the sun and to the right of it; the fourth 16' from the sun and to the right of it; the fifth 16' from the sun and 135° from the vertical; the sixth 8' from the sun and 135° from the vertical. These points were selected before the eclipse, but it was not known to Dr. Hastings in what order they would be viewed, so that the readings were absolutely free from bias. The position of the pointer of the polariscope was carefully verified before and after the totality. The readings were reduced immediately, and each reading (which was, as is evident, independent of every other) agreed in showing that the plane of polarisation was perpendicular to the sun's radius through the point examined—that is, *tangential*—a most unexpected result, about which, however, there is no doubt whatever. Four of the readings were made with a dark band in the centre, and two with a bright band. This result does not agree with others from the same eclipse, for the reason that in the method adopted by Prof. Morton, Mr. Lockyer, and others; there was, first, no means adopted for isolating a definite portion of the corona and determining its special polarisation. Second, that in the use of the Savart form, the phenomena of radial or tangential polarisation alike present bands radial to the sun. Third, that, with the bi-quartz, the field is so small that it becomes extremely difficult to interpret the tints of colour seen, if indeed any are seen. The novel fact was shown, by the use of this method, that the polarisation of the corona was exceedingly strong near to the sun's limb (one and a half minutes), and was relatively weak far from it."

I believe that no one is more astonished than Prof. Hastings himself at the result of his work, which, it has been laughingly said, goes to demonstrate the existence of *ice crystals* in the corona. With reference to the remarks made on my 1871 work in the foregoing, I may add that I used a bi-quartz and a large field, so that the objections raised to the method do not apply.

This brings me to the end of my notes for the present on the photographic, spectroscopic, and polariscopic results obtained. Of course there was a whole world of wonders outside these fields of inquiry.

The view of the shadow of the moon from the summit of Pike's Peak cleaving its way along the lower air has been described to me as one of the most striking phenomena which it is possible to witness or imagine. The shadow, the boundary of which was seen curved, was preceded and followed by a spectrum. Where I was, nearly 8,000 feet high, and therefore a little over mid-height, there was no effect on the air, but after the close of totality the shadow was observed passing over clouds near the horizon. I may add, however, that the phenomena at the beginning and end of totality hardly existed

for me, for I had to uncover and cover my photographic plates at those times.

It was not to be expected that in this country, where the anxiety for news and views seems always to be at fever heat, the astronomers would be allowed to quit their stations without giving an idea of the tendency of their work, and even its connection with the torrid temperature through which we have had to make our dusty way, or in which we have had to exist when locomotion had become impossible.

The utter disappearance of the large bright red corona of former years in favour of a smaller and white one in this year of minimum, struck everybody. Indeed it is a remarkable thing that after all our past study of eclipses this last one should have exhibited phenomena the least anticipated. It isolates the matter that gives us the continuous spectrum from the other known gaseous constituents. The present eclipse has accomplished, if nothing else, the excellent result of intensifying our knowledge concerning the running down of the solar energy. With the reduction of the number of spots or prominences for the last four years the terrestrial magnetism has been less energetic than it has been for the preceding forty years, while at both ends of this period we have had famines in India and China.

As the sun is the great prime mover of earth, and as every cloud, every air current depends upon it, its present quiet condition is worthy of the most minute study. The absence of lines from the corona spectrum shows a great reduction in the temperature of the sun, and such a marked change in the sun should produce a corresponding change on the earth, so that the associated terrestrial phenomena should be carefully observed. Hence I regard this eclipse as the most important that has been observed for many years as it throws much needed light on many points hitherto obscured in doubt.

Prof. Morton, of the Stevens Institute of Technology, remarked that the thing which impressed him most was the very curious character of the result; while on former occasions there has been projected into the space surrounding the sun a quantity of self-luminous gaseous matter which has no fixed place there, we now see that this was merely a temporary occupant which has, either by diffusion into space or absorption into the body of the sun, been removed. He also holds that the marked changes in the sun's condition would seem to call for corresponding marked changes in the condition of the earth. The results, in fact, recall to his mind one of the early theories of the maintenance of the sun's heat, which was that it was maintained by the impact of meteoric matter constantly falling in upon the sun from surrounding space. The quantity of heat produced by such an infall may be realised from the fact that a body so falling would develop by impact as much heat as 5,000 times its weight of carbon burnt in oxygen. Portions of the meteoric matter in the shape of meteorites fall upon the earth, and we thus know that most of them consist largely of iron, containing considerable quantities of absorbed gases; others are of a metallic character and devoid of such gases. If, now, we suppose that for a considerable period the sun's fires were fed with hydrogen-charged faggots, and then again that the main supply was of mineral matter, we might have at first a far-reaching atmosphere





vious days had strongly shown the advantage of separating the parties as much as possible. We chose a spot to leeward of one of the enormous water tanks of the Union Pacific Railway, which form the chief features in the interesting but desolate plains in that region, over which the wind sweeps at times with incredible violence.

On reaching our destination we found Prof. Newcomb, whose camp was about a mile away, and it was then agreed that as both he and Prof. Watson were to hunt for the planet they had better be together, so I lost his company during the eclipse.

Prof. Watson's plan of operation was to sweep south of the sun and observe all the stars in the map, a part of which is here reproduced (Fig. 6), and to refer the position of any new body to the stars, or, if possible, to the sun itself. For this purpose, with the assistance of the Rawlins carpenter, he armed his equatorial with paper circles and brass wire pointers. He commenced operations to the left of the sun and saw the stars marked, but none others. Then sweeping out to the star marked *b* he noticed on his return another not on the chart, marked *a*. He then made three marks on his right ascension paper circle, on the spots occupied by the pointer, when the sun, *a* and *b*, were successively brought into the centre of the field. He next determined the difference of declination in the same way between the sun and *a*, having the additional help that *a* was nearly in the same declination as *b*. He then repeated his R.A. measures, and called Prof. Newcomb, but the eclipse was over before anything more could be done. I give this statement from memory only (as I was too busy to make notes at the time), as I heard it soon after the eclipse at the camp, before the telescope was dismounted. It is probable that subsequent careful measures of the circles may alter the place—

R.A. 8h. 26m.  
Dec. + 18° 00'

I telegraphed to you, somewhat, but the alteration will be small.<sup>1</sup>

Since arriving here I have learned that Mr. Swift, of Rochester, a well tried observer, also saw the planet. The first account I read of his work was as follows:—

"This gentleman made a very careful search for Vulcan, scanning the heavens very closely with his splendid comet eye-piece, made by the celebrated Gundlach, but he saw nothing of it. He did, however, see, about three degrees from the sun, two stars not down in the charts or star maps, and about as bright as the pole star—they were pointing directly towards the sun. On attempting to re-find them, he was prevented by a little cloud."

Since then, however, another fuller account of his work has appeared, from which I gather that about one minute after the commencement of totality two stars caught his (Mr. Swift's) eye about three degrees, by estimation, southwest of the sun. He saw them twice, and attempted a third observation, but a small cloud obscured the locality. The stars were both of the fifth magnitude, and but one is on the chart of the heavens. This star he recognised as Theta in Cancer. The two stars were about eight minutes apart. There is no such configuration of stars in the constellation of Cancer. In 1859 the French

<sup>1</sup> On going to press we receive a letter from Prof. Watson, dated Ann Arbor, August 14, stating that the result of more careful examination gives—Washington M.T., July 27, 5h. 16m., R.A. 8h. 26m. 54s., Dec. + 18° 16'.

astronomer, Lescarbault, claimed that he had seen an intra-Mercurial planet crossing the sun's disc. He related his discovery to Leverrier, who became a firm believer in the existence of such a planet. The perturbations of Mercury's orbit demand such a planet as Leverrier named Vulcan. The star Mr. Swift saw may have been the same that was seen by Prof. Watson, who was located at Rawlins, Wy. T.

Mr. Swift possessed a comet eye-piece of very flat and large field, and distinct to the very edge. It was made in Rochester, and to it and his blunder in failing to untie his instrument, he believes he owes his success.

The instrument used in the search for Vulcan by Prof. Holden proved to be inadequate to show all the stars on the Washington star map, owing to the brightness of the corona. The space where the planet seen by Prof. Watson was, was four times swept over, but so near to the sun as this, a four and a-half magnitude star was not to be seen. A space of 10° in declination by 35° in right ascension was twice swept over.

Here, again, we get an idea of the thoroughness with which the work has been planned and executed.

It would be wrong to conclude these hurried notes without stating that, from the day in which I landed in New York to the present time, I have become everybody's debtor for acts of kindness, which have touched me greatly. This great country is a land of true courtesy, for which I here express my gratitude, not only to my scientific brethren, and chiefly to Dr. Draper, General Myer, and Prof. Newcomb, whose guest I have been, but to hundreds to whom I have been a stranger and unknown.

As significant of the keen interest taken in the eclipse by all classes here, I may mention, in conclusion, that on the Sunday before the event prayers for fine weather were offered in all the churches of Denver.

Washington, D.C., Aug. 8 J. NORMAN LOCKYER

AS I have been recently giving attention to the subject of solar spectroscopy in consequence of my discovery of oxygen in the sun, it seemed desirable to take advantage of the total eclipse of July 29, to gain as precise an idea as possible of the nature of the corona, because the study of that envelope has been regarded as impossible at other times. The main point to ascertain was whether the corona was an incandescent gas shining by its own light, or whether it shone by reflected sunlight.

For this purpose I organised an expedition, and was fortunate enough to secure the co-operation of my friends Professors Barker and Morton, and Mr. Edison. The scheme of operation was as follows: (1) the photographic and photo-spectroscopic work, as well as the eye slitless spectroscope were to be in charge of my wife and myself; (2) the analysing slit spectroscope was in charge of Prof. Barker, with the especial object of ascertaining the presence of bright lines or else of dark Fraunhofer lines in the corona; (3) the polariscopic examinations were confided to Prof. Morton, who was also to spend a few moments in looking for bright or dark lines with a hand spectroscope; (4) Mr. Edison carried with him one of his newly-invented tasimeters with the batteries, resistance-coils, Thomson's galvanometer, &c., required to determine whether the heat of the corona could be measured.

This entire programme was successfully carried out,